PEBB-Based Aircraft Electrical Service Stations

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Purpose

- To develop and test a prototype Aircraft Electrical Service Station (AESS) power supply based on Power Electronic Building Block (PEBB) technology
- This 90 kVA AESS system is intended to supply 400 Hz AC and 270 Vdc power onboard aircraft carriers

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Background

- Aircraft carriers require 400 Hz power for:
  - Servicing aircraft via AESS stations
  - Repairing and maintaining aircraft electronics in shipboard avionics shops
  - Other miscellaneous loads (radar and combat system components, etc.)
- Existing aircraft carrier 400 Hz power is supplied by:
  - 60 Hz to 400 Hz motor generator sets
  - 450V to 120V transformers
  - Line voltage regulators to boost voltage to the aircraft

Background (Cont'd)

- The existing 400 Hz system:
  - Is frequently unreliable
  - Has many high-maintenance components
  - Does not supply the 270 Vdc power required for new aircraft
- Therefore, ONR has funded development of a new AESS system
  - Based upon ONR's PEBB technology
  - Designed to eliminate the current AESS problems
  - Will replace the existing motor generator sets, transformers, and line voltage regulators

Objectives

- Develop an AESS system based on PEBB technology to supply 400 Hz AC and 270 Vdc loads onboard aircraft carriers and other naval ships
  - Determine the actual system requirements
  - Use extensive modeling and simulation to improve converter design and mitigate risk
  - Improve existing AESS reliability and power quality
- Test the prototype PEBB-based AESS system
  - Using land-based naval aircraft
  - With carrier-based aircraft at sea

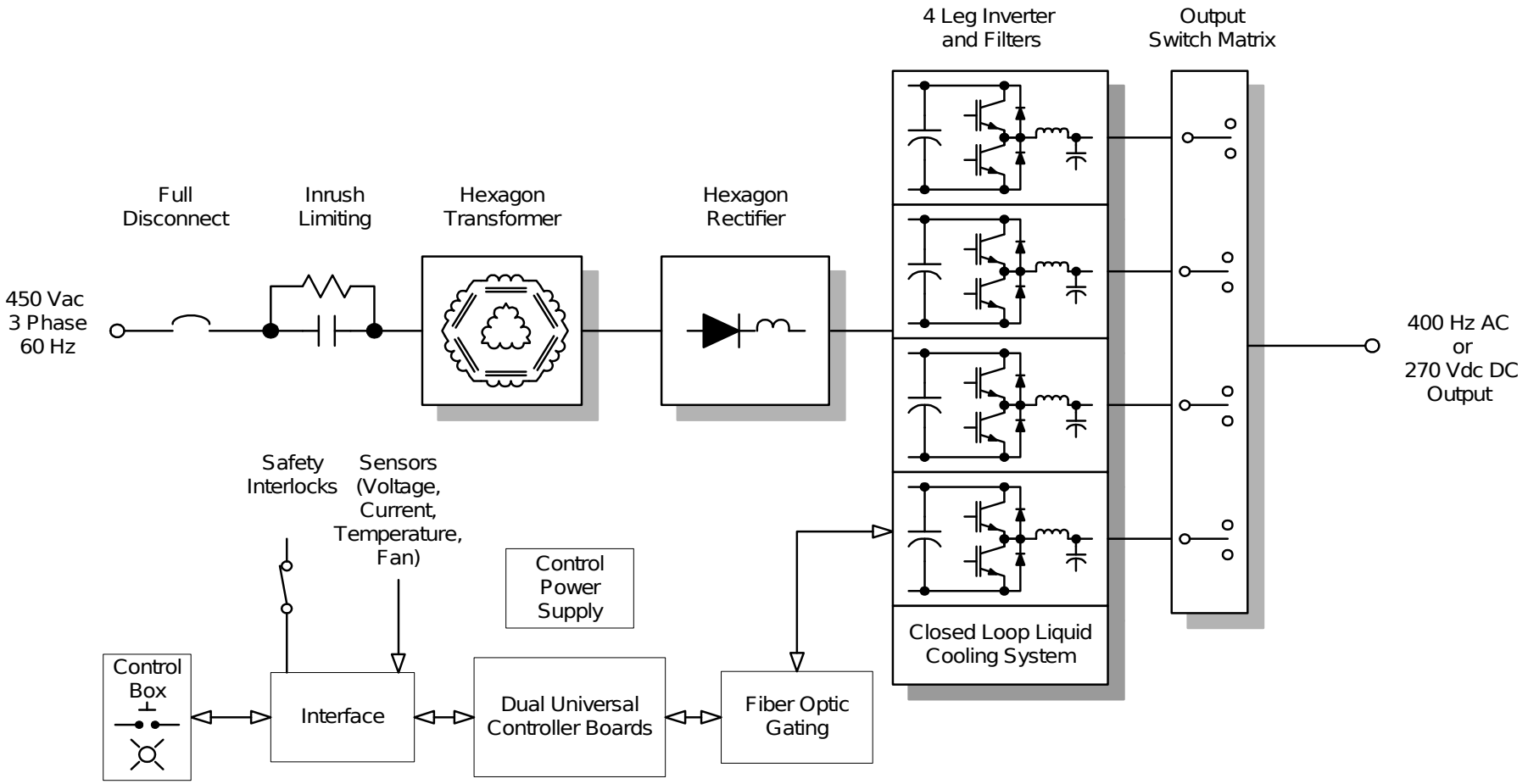
Team Members

- **Office of Naval Research** - Overall program responsibility and funding
- **Northrop Grumman Newport News** - Program management, requirements definition, electrical system design, and stability analysis
- **Northrop Grumman Electronic Systems** - AESS system design, construction, and testing
- **SUPSHIP Newport News** - Program and technical support and consultation
- **Naval Surface Warfare Center** - CVN 400 Hz system lessons learned and historical data
- **University of South Carolina** - System level modeling and simulation using the Virtual Test Bed
- **Virginia Tech** - Component modeling, EMI analysis, controller development, and converter design support

Benefits

- Reduced maintenance and repair requirements
  - Lower life cycle costs and manpower reductions
- Improved performance, reliability, and power quality
- Support for future aircraft:
  - Increased power output (90 kVA vs. 60 kVA)
  - 270 Vdc capability
- Reduced demand for mobile power equipment on carrier flight decks

High Level Architecture



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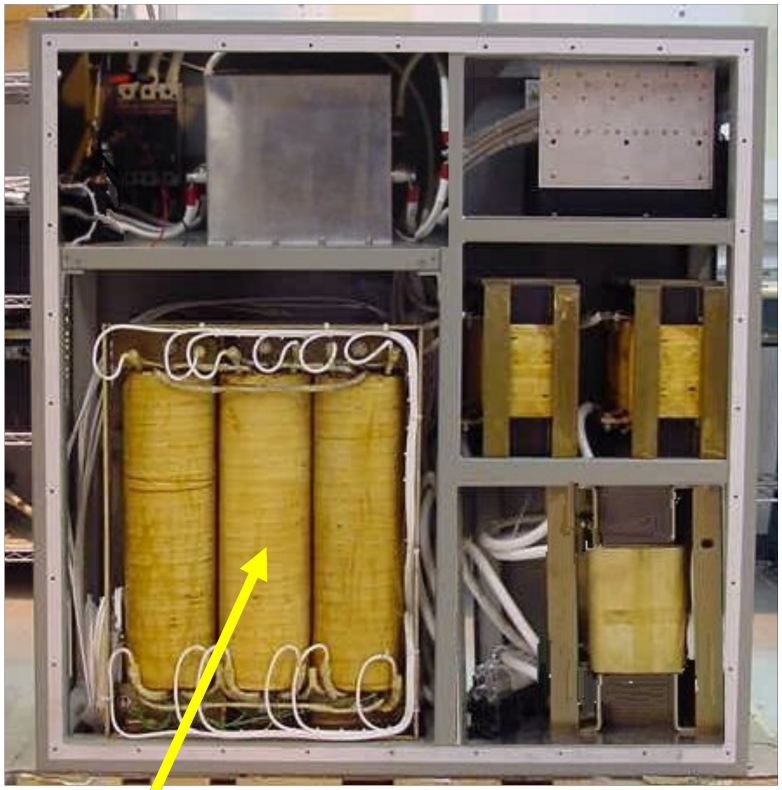
Rectifier Cabinet

EMI Filter

Circuit Breaker



Diode Rectifier

Commutation Inductors

Hex Transformer

DC Link Inductor

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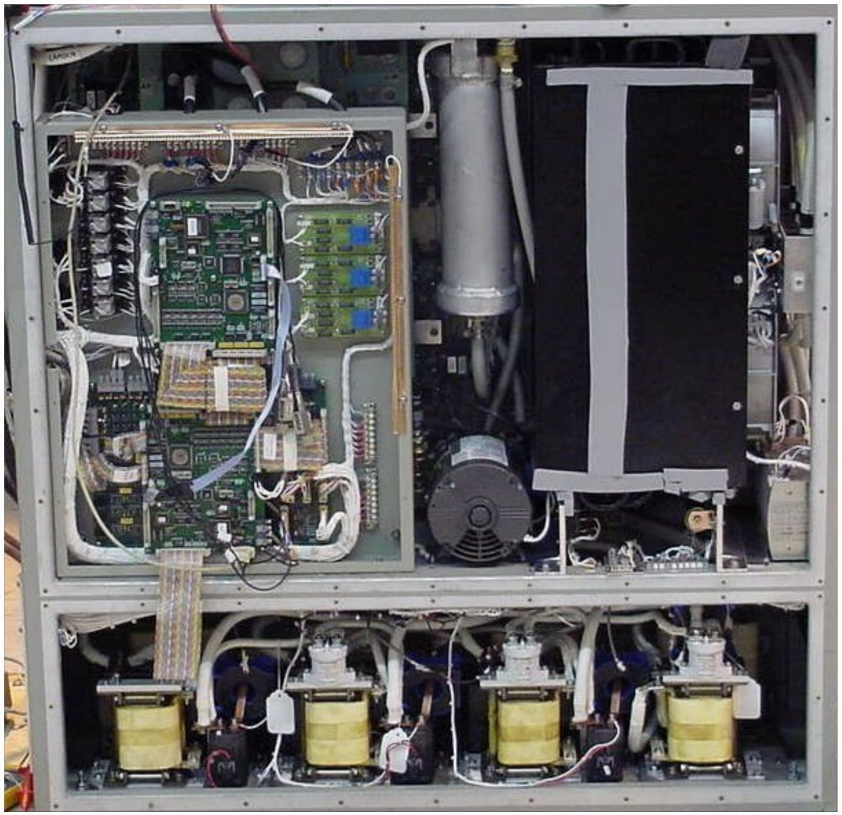
Inverter Cabinet

Universal Controller Boards

Inverter Phase Legs

Radiator



Power Board

Interface Board

Output Filters

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Key Specifications

- Rated load – 90 kVA
- Input:
  - 440 Vac, 60 Hz, 3-phase
- Output:
  - 115/200 Vac, 400 Hz
  - 270 Vdc
- 15% unbalanced AC load
- Power factor – 0.5 lagging to 0.8 leading
- MIL-STD-1399, 4-wire, Type III AC output
  - 1% voltage tolerance (aircraft)
  - ½% voltage tolerance (avionics shops)

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Key Specs (Cont'd)

- MIL-STD-704 aircraft power requirements met
- Both MIL-STD-1399 and MIL-STD-704 limits for output voltage harmonic distortion met when supplying up to 45 kVA nonlinear load
- AC overload rating up to 225% for 3 seconds
- Individual phase cable drop compensation (up to 10%)
- Efficiency:
  - 89% at 50% load
  - 92% at 100% load
- MIL-STD shock, vibration, EMI

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Enhanced Requirements

- Stability
  - Requirements on load impedances imposed to ensure that multiple converters in parallel are stable at the 60 Hz bus interface
- Input current harmonics
  - Higher frequency current harmonics restricted (greater than MIL-STD-1399 limits)
  - Prevents excessive high frequency voltage distortion
- Voltage regulation
  - Regulation requirement at aircraft interface strengthened from +/-2% to +/-1%
  - Ensures MIL-STD-704 limits are met for aircraft loads

Enhanced Requirements (Cont'd)

- Current limiting
  - Short circuit requirement enhanced
  - Ensures tripping downstream breakers for shipboard loads
- Leading power factor loads
  - Requirement added to ensure the system can supply loads with highly leading power factors, such as avionics shop test equipment
- Motor starting
  - Requirement added to ensure that aircraft compressor loads can be started
  - Motor starting is traditionally a weakness for frequency converters

Special Features

- Controller specifically designed to:
  - Compensate for unbalanced phase loads
  - Cancel selected output harmonics
    - 3rd, 5th and 7th harmonics targeted
- Sophisticated cable compensation technique
  - Compensates for voltage drop in a variety of cable types
  - Stored presets for voltage regulation range, cable types, and conductor configurations
  - Automatically applies proper compensation voltage given user input of cable types and lengths

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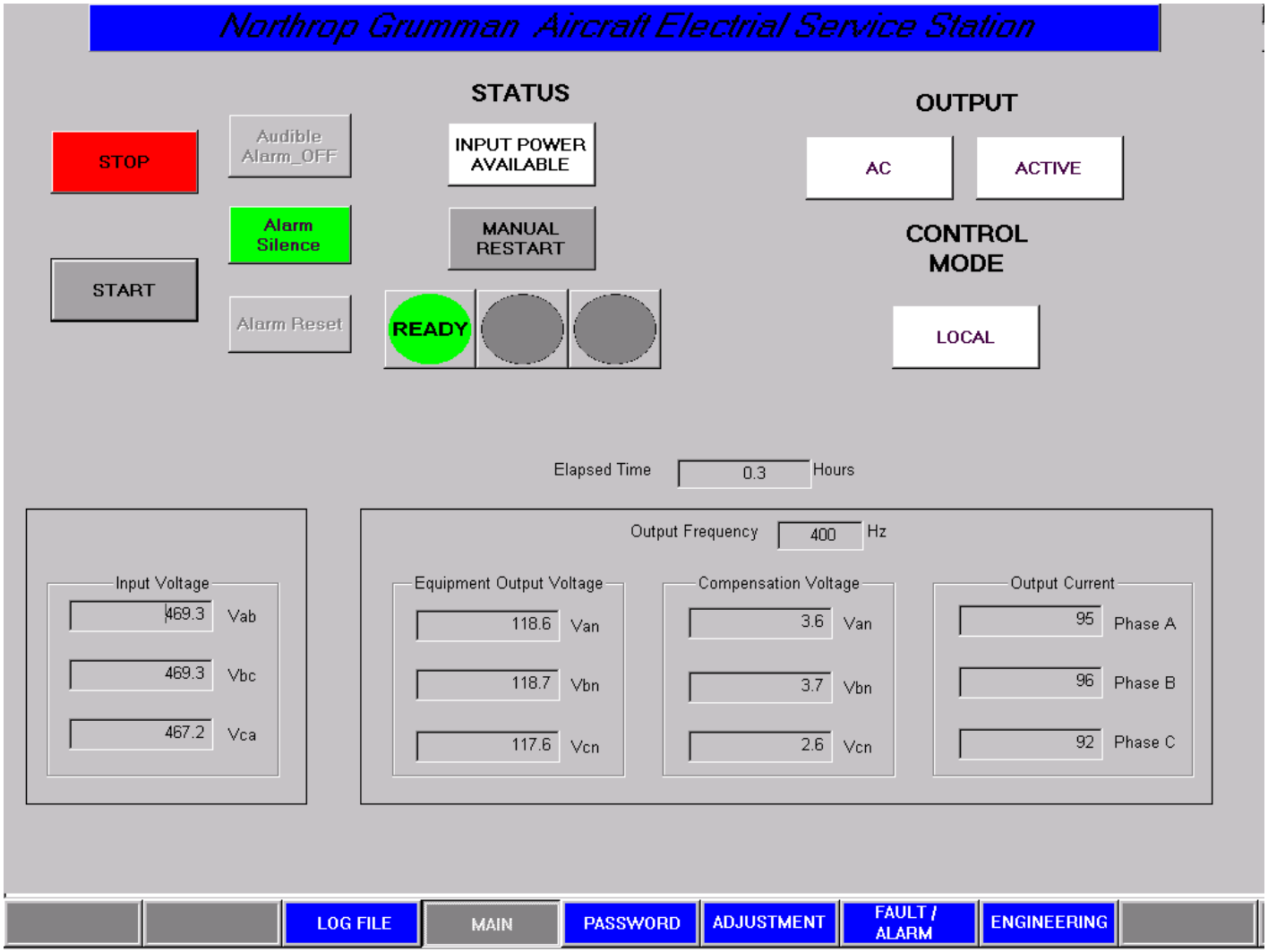
Operator Panel - Main Screen



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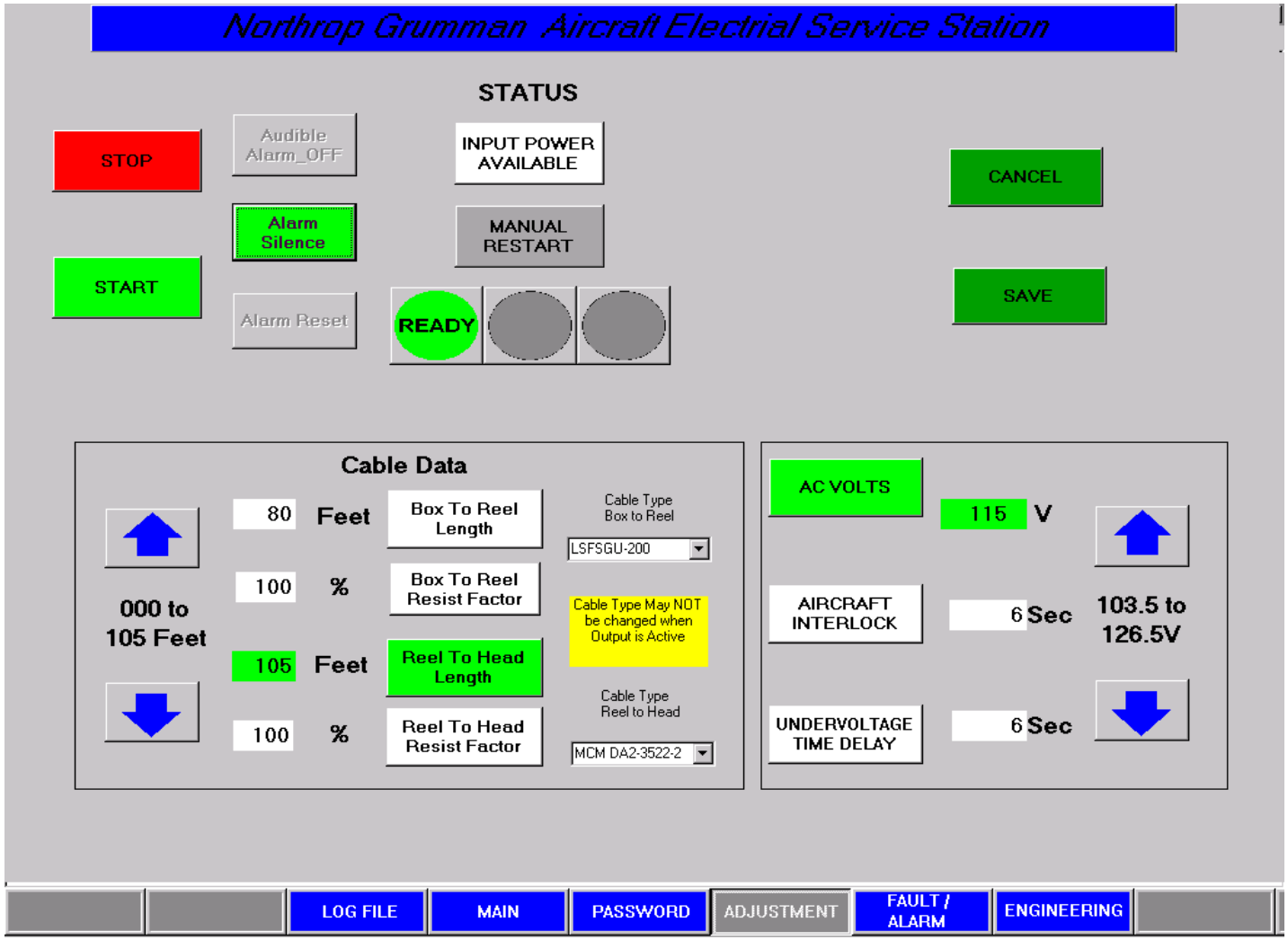
Operator Panel - Adjustment Screen



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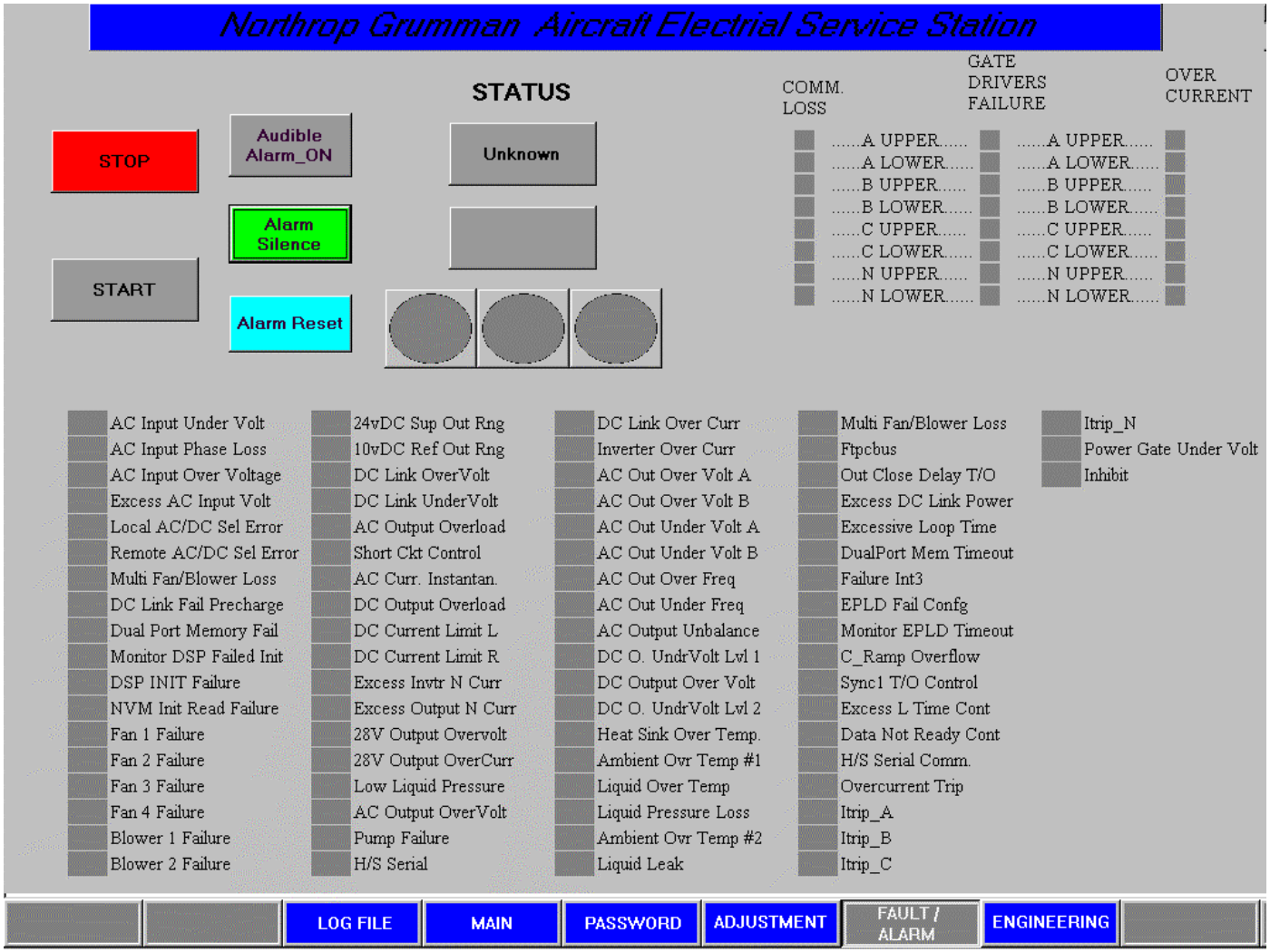
Operator Panel - Fault/Alarm Screen



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Status

- Specification developed (5/01)
- Prototype converter completed (11/01)
- Testing at NAVAIR (Pax River):
  - EMI testing (12/01)
  - E-2C 2000 testing (1/02)
  - Helicopter simulator testing (1/02)
- Aircraft carrier testing:
  - Installed on CVN 75 (2/02)
  - E-2C 2000 testing (3/02)
  - At-sea testing (3/02 – 10/02)